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Telemedicine in Stroke: Potentials, Limitations and Ongoing Issues

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1. Introduction

1.1 The burden of the disease

Stroke is a high frequency neurological disorder and the most common cause of complex disability in adults (Adamson et al. 2004). It is the second and third most common cause of mortality in the developing and developed worlds respectively (Lyons & Rudd 2007). In the United States, 780,000 people per year experience either a new or a recurrent stroke. In 2004, stroke mortality was estimated to be in excess of 150,000 and the prevalence of stroke in people over the age of 20 was 5.8 million in 2005. About 30% of stroke survivors are permanently disabled and about 20% require institutional placement at three months (Rosamond et al. 2008). Stroke is an example of a largely preventable disease that presents acutely, with a short time window for amelioration. It is associated with a high mortality rate, a significant risk for residual disability, and has a large impact on society, the patients and their families (Demaerschalk et al. 2010). Stroke recurrence can lead to a stepwise decline into dependency, resulting in a financial burden on society. According to Rosamond et al (2008), the indirect and direct costs of stroke in the United States were calculated at \$65.5 billion in 2008. The majority of strokes are due to cerebral infarction (87%) and as such are amenable to a variety of pre-stroke risk factor modification strategies, as well as thrombolysis or intravascular clot retrieval strategies during the acute phase (Hachinski 2002; Yusuf 2002; Rosamond et al. 2008). The remaining subtype of stroke, i.e. intracerebral haemorrhage, is largely preventable by pre-stroke blood pressure control (Hachinski al. 2010).

1.2 The rural challenge

Globally, the majority of strokes occur in rural areas where there is often a lack of stroke services. In these areas, stroke care is often fragmented and does not adhere to recommended guidelines (Hess et al. 2005; Joubert et al. 2008). This, together with the world-wide focus on provision of health services, the geographical barriers that are associated with a general attenuation of access to healthcare resources and the paucity of

stroke experts results in an inequitable distribution of resources, which frequently limits access to evidence-based care (Park & Schwamm 2008). Service delivery is frequently variable even within developed countries, but even more so in developing countries. In rural Australia, for example, over 90% of hospitals have 24-hour access to CT scanning, but residents have to travel, on average, about 100km. A study carried out in Montana and Northern Wyoming by Okon et al (2006) revealed that only 39% of hospitals had 24-hour CT capabilities. A study in China by Liu et al (2007) showed the use of CT in rural areas to be “low” compared to urban areas, but exact data are not available. In India, there are no reliable data on rural Indian CT services. In a study of stroke services in 21 rural hospitals in Idaho by Gebhardt et al (2006), 77.8% reported patient delays and 66.7% reported transport delays. There were equipment delays in 22.2% and ancillary service delays in 61.1%. Only 33.3% of hospitals were involved in quality improvement programmes, thrombolytic therapy was available for stroke in only 55.6% and no hospital had a designated stroke team. In Scotland, although it was revealed that the admission rate for symptomatic carotid disease was significantly higher in deprived rural populations, less carotid endarterectomies were performed in the rural compared to the urban areas. An assessment by Read et al (2005) of the differences in stroke care practices between regional and metropolitan hospitals in Australia showed that rural patients were less likely than their urban counterparts to receive CT of the head within 24 hours of admission, swallowing assessment, echocardiography, carotid imaging, lipid or glucose estimations or services from allied health professionals. Furthermore, no rural hospital in New South Wales had a stroke-specific clinical nurse compared with 21 stroke nurse case manager positions in metropolitan New South Wales, and only one third of the rural hospitals had access to a neurologist .

1.3 Telemedicine/Telestroke

Telemedicine has been defined as the delivery of healthcare services to the underserved, employing telecommunication (Misra et al. 2005). A more extensive definition is “the process by which electronic, visual and audio communications (including the telephone) are used to provide diagnostic and consultation support to practitioners at distant sites, assist in or directly deliver medical care to patients at distant sites, and enhance the skills and knowledge of distant medical care providers (Deshpande et al. 2008).

“Telestroke” refers to the application of telemedicine to stroke care. It is a new application of existing technology in the care of stroke patients (Sato & Ohta 1993). Demonstration projects have proven the feasibility of telestroke (Goldstein & Rothwell 2007) and suggested its potential to facilitate access to specialist stroke expertise in hospitals without access to specialist clinicians. Importantly, use of this technology may promote implementation of best-practice management of vascular risk factors in the stroke survivor after discharge (Bouffard 1997; Susman 1997; Park & Schwamm 2008). The main drivers have been technological advances, such as the digitisation and compression of data permitting the rapid transfer of images (Levine & Gorman 1999).

2. Current and potential uses of telestroke

Telemedicine, as a distant communication tool, was first attempted in radiology 50 years ago (Jutras 1959) and subsequently in psychiatry (Wittson et al. 1961). Since 1999 there has been a gradual increase in telemedicine programmes and, more recently, a growing interest in its use in stroke, mainly in facilitating thrombolysis, (Wang 2003; Audebert 2006; Park &

Schwamm 2008), but also in establishing diagnoses and guiding treatment options (Wiborg & Widder 2003).

Telestroke has the potential to improve the care of the stroke patient in the acute phase, the subacute phase, the rehabilitation phase and in the long term for the prevention of recurrence of cerebrovascular or cardiovascular events. Attention at all these levels can substantially lower the net cost of the condition to society by reduction of lost productivity, nursing home costs and rehabilitation (Hachinski et al. 2010). So, although in the past telemedicine has mainly focused on the area of thrombolysis in the acute stage of the disease, it has now been acknowledged to have the potential to also bring substantial benefits to the remaining stages of the stroke victim's journey.

2.1 Telestroke for acute stroke management

Thrombolysis of acute ischaemic stroke

The Recommendations for the Establishment of Stroke Systems of Care by the American Stroke Association (ASA) task force state that:

"A stroke system should make certain that clinical pathways are used consistently to ensure the organized application of interventions to prevent or limit stroke progression or secondary complications" (Schwamm et al. 2005).

The current and most common use of telestroke is to provide specialist expertise to distant sites in the administration of recombinant tissue plasminogen activator (rt-PA). The importance of this treatment is that the majority of strokes are ischaemic (87%) and if the cause for the ischaemia can be removed within a three hour time-window (and possibly longer) there is a significant reduction in the amount of damage to brain tissue compared to cases where ischaemia is left unresolved for many hours or days. In this context, as has been often stated, "Time is brain". Since 1996, rt-PA has been approved by the US Food and Drug Administration as the only treatment for ischaemic stroke with the express goal of reducing neurological damage, improving recovery and reducing disability (Demaerschalk et al. 2010). In the landmark study of the National Institute of Neurological Disorders and Stroke (NINDS), a randomised, double-blind trial where 624 stroke patients were either administered placebo or rt-PA within 3 hours of the onset of stroke symptoms, significantly more patients in the rt-PA group had a favourable outcome compared to those in the placebo arm of the study (odds ratio, 1.7; 95% confidence interval, 1.2-2.6). Thus at three months after the stroke, 31% to 50% of those who were administered rt-PA had minimal or no disability compared to 20% to 38% of the placebo group. There was an increase in intracerebral haemorrhage in those treated with rt-PA (6.4 % vs. 0.6%) but at three months, there was no difference in mortality rates between the two groups (17% for rt-PA group and 21% for the placebo group) (Demaerschalk et al. 2010).

Despite the recommendations from the American Heart Association (AHA)/ASA for the use of rt-PA in acute stroke subject to stringent guidelines, because of the constraints imposed by the time-window, as well as apprehension from treating physicians of the complication of haemorrhage, only a minority (2%-3%) of stroke victims receive this form of therapy (Alberts et al. 2000). This may change with attempts to widen the time-window to 4.5 hours, following the results of the European Cooperative Acute Stroke Study (ECASS III) (Hacke et al. 2008).

As a result of the limitations described above, the Joint Commission commenced the certification of hospitals as Primary Stroke Centres (PSCs) in 2004, and by 2006, 200 such

centres had been certified in the United States (Demaerschalk et al. 2010). Since the AHA/ASA guidelines were determined, such PSCs have used telestroke in areas which, due to geographical or other reasons, require distant support in the evaluation of patients who could benefit from thrombolysis. Meyer et al (2008) reported that a telemedicine network in Southern California has treated 28% of ischaemic stroke patients with rt-PA in this way. Similarly, an evaluation by Lattimore et al (2003) of 8 PSCs in Phoenix, Arizona demonstrated that 18% of patients with cerebral infarction were treated with rt-PA and in Bethesda, Maryland, a PSC reported an increase of use of rt-PA in acute stroke from 1.5% to 10.5%. These data indicate that medical services that normally would avoid using thrombolytic therapy for a variety of reasons, when supported by stroke centres, usually by a telestroke link-up, will offer acute stroke victims the opportunity to receive this evidence-based treatment accepted by the Food and Drug Administration for the treatment of acute ischaemic stroke.

In a recent systematic review by Johansson and Wild (2010), of the fifteen studies using telestroke reviewed, all reported that implementation of a telestroke-guided distance treatment with rt-PA was not only feasible, but acceptable. In one of the earliest telestroke networks, the TEMPiS network in Bavaria, Audebert et al (2006) reported improved health outcomes and a reduction of mortality at three months post stroke. A variety of telestroke modalities was used including telephone support and two-way real-time videoconferencing. The review has raised the need for further studies to counter the lack of standardized reporting of outcomes and the use of facilities and resources as well as economic studies addressing the use of telestroke.

Pre-hospital diagnosis and evaluation of suitability for thrombolysis

Urban situations are more likely to have readily accessible rapid response transport, e.g. MICA ambulance, for the acute stroke patient. In more isolated or rural settings, these options may not be as readily available, and a degree of screening may therefore be useful. Pilot studies have been carried out which have employed telestroke technology as a method of screening eligible patients and, in particular, assessing stroke severity (LaMonte et al. 2004). This is obviously a useful employment in remote areas, such as the Australian Outback, particularly for clinic nurses when vast distances are involved. However, the cost-effectiveness and reliability of this method still need to be tested in a controlled trial situation.

Virtual neurological assessment and identification of stroke "mimics"

An important feature of telestroke consultations is that with real-time videoconferencing, geographically distant sites can benefit from visual confirmation of the stroke diagnosis. There are several mimics of an acute stroke including hypoglycaemia, epilepsy, hysteria and movement disorders (Pfrieger 2009). Many of these can be quickly identified by experienced physicians, and so avoid unnecessary transport and promote the correct treatment. In a study comparing the initial diagnosis, before imaging, between emergency physicians, primary care doctors and stroke experts, the rate of misdiagnosis by non-stroke doctors was 30%. This area of real-time video consultation by experienced neurologists has significant implications both in terms of cost-saving as well as patient welfare (Hachinski et al. 2010).

Neurological advice in complex cases

Small hospitals at a distance from PSCs often have the ability to implement suggestions that would save a patient being transported at cost to the PSC. Complex problems such as diabetic control, management of dissection or timing of interventions (such as

anticoagulation after a stroke) can all be the subject of videoconferencing, with great benefit to the distant hospital and improvement in patient care. In addition, expert advice can be given regarding management of raised intracranial pressure, appropriateness of transfer for decompressive surgery and treatment of post-stroke seizures (Schwamm et al. 2009).

Screening and facilitation of management of suspected Transient Ischaemic Attacks (TIAs)

TIAs are often neglected or misdiagnosed by non-neurologists. Expedited evaluation and prompt management by stroke experts has demonstrated a lower than predicted subsequent stroke rate, but in rural or geographically isolated areas, the delay between TIA and evaluation is often protracted. This can have serious consequences since certain TIA subsets are associated with very high risk of future stroke. Patients with an ABCD2 (Age, Blood Pressure, Clinical Features, Duration and Diabetes) score of 4 or higher have a particularly high subsequent stroke risk (Uchiyama 2009). Prompt evaluation and immediate treatment is important in TIA patients since the longer the wait after the TIA, the higher the risk of stroke (Lavalley et al. 2007). The ASA has suggested that telestroke has the potential to provide the needed specialist input (Schwamm et al. 2009) but this model has yet to be evaluated. Telestroke screening by experienced clinicians will allow for identification of TIA mimics as well as true TIAs, especially those posing the greatest threat, and facilitate effective triage and management.

2.2 Telestroke for Subacute Stroke Management & Rehabilitation

Augmentation of existing facilities in subacute care scenarios

The Recommendations for the Establishment of Stroke Systems of Care by the ASA task force state that:

“A stroke system should use organized approaches (e.g., stroke teams, stroke units, and written protocols) to ensure that all patients receive appropriate subacute care” (Schwamm et al. 2005).

Govan et al (2008) have unequivocally demonstrated that the care of stroke patients in dedicated stroke units reduces institutionalisation, lowers stroke-related mortality and enhances functional outcome. About one third of all stroke patients deteriorate within the first 48 hours after a stroke (Castillo 1999) and the increased mortality and morbidity during the in-hospital phase is directly related to this deterioration. Common causes are conditions such as urinary tract infections, development of aspiration and hypostatic pneumonia and fluctuations of blood pressure. The elements of care that are needed are not complex; they consist of simple guidelines such as assessment of swallowing and avoidance of hyperthermia (Adams et al. 2007). These considerations, often not part of the general ward routine, can be transmitted by experienced stroke teams by telestroke contact and education. Thus, the expertise from stroke specialists in the subacute phase can be made available to smaller centres which do not deal with these issues on a daily basis. With a widespread lack of direct contact with stroke specialist teams (Trimble et al. 2007), telestroke can augment a rudimentary clinical situation so that the required guidelines are followed. The clinical approach to symptomatic carotid stenosis is different to that required in embolic stroke secondary to atrial fibrillation. Guidance in this stage where stroke subtype differentiation informs treatment can be furnished by telestroke contact. Intimation of the effect of telestroke in this regard has emerged from studies in Germany. In the Bavarian TEMPis project by Audebert et al (2006), part of the telestroke initiative consisted of providing protocols for management, ongoing medical education and a comprehensive quality

management programme. Of the 3122 patients enrolled in the programme, 37% were admitted to 5 control regional hospitals without telestroke support, while 63% were admitted to 5 regional hospitals where telestroke support was available. In those hospitals supported by the telestroke system, more patients received rt-PA, and appropriate investigations were more commonly performed. Thus, rapid brain imaging (74% versus 32%), carotid Doppler studies (83% versus 32%) and swallowing evaluation (73% versus 48%) all indicated more appropriate early management of stroke patients. At three months after the stroke, fewer patients were disabled, placed in institutions or dead in the telestroke-supported distant hospitals. In fact multivariate analysis demonstrated a lower probability of poor outcome in these hospitals (OR 0.062, 95% CI 0.52 to 0.74). The TEMPiS study clearly demonstrated that not only for guidance in thrombolysis, but also at the subacute stage, telestroke support provided an augmentation of services at a distance, which was significant not only in terms of process but also outcomes.

The TESS (Telemedicine in Stroke in Swabia) programme supported the above findings; post-hoc evaluation indicated that in more than 75% of cases, useful advice was obtained regarding radiological evaluation, stroke diagnosis and management via telestroke contact (Wiborg & Widder 2003). Telestroke systems are therefore in a position to provide expert advice from stroke specialists to community and other hospitals in the subacute management of patients who have been admitted with a stroke. In particular, this advice and support will help prevent complications in the immediate post-stroke period as well as encourage the initiation of the correct therapies such as anticoagulation at appropriate times and management of blood pressure discrepancies. It can also help to encourage application of the recommendations of the ASA task force (Schwamm et al. 2005).

Rehabilitation in subacute stroke

The Recommendations for the Establishment of Stroke Systems of Care by the ASA task force state that:

“Stroke patients should be referred to an inpatient facility, an outpatient facility, or a home care service that provides for their medical and functional needs” (Schwamm et al. 2005).

Many stroke sufferers lack access to rehabilitation services (physio-, speech and occupational therapy). There are many reasons for this including overload of services, financial constraints for the victim or family and geographic limitations (Frankel et al. 2007). Moreover, although stroke rehabilitation is effective, often neither the time nor the intensity is available from stretched resources (Hachinski et al. 2010). If this is so in the urban setting, it is manifestly more so in the rural areas of the world. Simple educational teleconferencing adapted to local circumstances can, even if only partially, bridge the gap between need and delivery. Show-and-tell educational programmes can involve and make use of family members and friends in the implementation of evidence-based rehabilitation strategies. This is particularly applicable in the developing world. Telecommunication has the potential to bring expertise from multidisciplinary teams to a vast number of stroke survivors at very low cost, but the effect of telecommunication in providing such education in stroke survivors has not yet been adequately evaluated.

The challenge is to be able to evaluate the relative value of each rehabilitation activity in terms of return per unit of investment of time, resources or both (Hachinski 2001). Apart from traditional methods, the AHA/ASA has endorsed the development of novel technology-assisted rehabilitation modalities (Hachinski et al. 2010). Electronic communication between stroke survivors anywhere in the world and stroke experts has

tremendous potential to promote self-management. Creativity will be the key, and telecommunication, in particular videoconferencing, should provide the vehicle of communication. A telemedicine programme can therefore be of use not only in a community hospital setting, but also in the organisation of home rehabilitation, thereby allowing the recommendations of the ASA task force to be followed in all settings.

Psychiatric evaluation and intervention

Telemedicine in the form of videoconferencing was, from a very early stage in its history, used for long-distance psychiatric evaluation and treatment, and was found to be effective (Doze et al. 1999; Matsuura et al. 2000; Simpson et al. 2001). A systematic review by Hackett et al (2005) of all published non experimental studies of depressive symptoms after stroke reported that one third of all people experience significant depressive symptoms at some time after the onset of stroke. The authors acknowledge, however, that this is probably a conservative estimate due to potential under-reporting or under-recognition of altered mood, and the difficulties typically associated with mood assessment of stroke patients, particularly when there are communication problems caused by dysphasia and/or dementia. The effect of this is to delay rehabilitation, to limit compliance with secondary prevention measures as well as to increase the long-term morbidity. Therefore, identification of post-stroke depression (PSD) is vitally important. Telestroke is a technology which would be ideal for periodic screening for depression as well as delivery of appropriate treatment. Again, as a member of the multidisciplinary stroke team, the psychiatrist can add a valuable segment to the armamentarium required to maintain the stroke chain of recovery. The effect of this form of surveillance and appropriate intervention requires evaluation in the future.

Social evaluation and intervention of patients, family and proxy

The social burden placed on stroke victims and their families is often enormous. Ongoing evaluation of the impact of stroke, particularly on the carers and families is seldom performed. The evaluation of social situations often requires skilled interviewing. This is another area in which a telestroke model has potential. As a member of the multidisciplinary stroke team, an experienced social worker can contribute vastly in bringing to light financial and other social problems, and providing expert advice either directly or via a proxy such as a district nurse.

2.3 Telestroke for secondary prevention after discharge from hospital

Importance of preventive strategies

The most effective way to reduce the burden of recurrent cerebrovascular disease on society is by prevention (Gorelick 1997). Long-term effective risk factor management presents a positive challenge to stroke management as the risk for recurrent stroke can be reduced by around 70-80% if simple best-practice recommendations are implemented (Hachinski 2002; Yusuf 2002). Unfortunately, secondary prevention measures are all too frequently sub-optimally implemented in stroke survivors (Jencks et al. 2000; Touze et al. 2008). In a recent landmark paper, Hachinski et al (2010) point out that despite the fact that stroke is increasing on a world-wide scale as the result of several well-known risk factors, these factors are frequently not well managed and are in fact neglected. There is a considerable degree of "therapeutic inertia" at primary care level and a high rate of medication discontinuation in stroke survivors after discharge (Dergalust et al. 2003).

For example, a large Swedish population-based cohort study of 28,449 participants by Li et al (2008) showed that in people with a history of previous stroke, 7.5 years after enrolment there was a high rate of hypertension (79.4%), only half were on anti-hypertensive medication and only 11.5% achieved a blood pressure < 140/90 mm Hg. In addition, the majority of stroke survivors with hypercholesterolaemia were not treated with lipid lowering medication, and antithrombotics were used in only 38%. One third was still smoking and two thirds were obese. The calculated stroke risk was significantly higher in stroke survivors than in people without stroke. The evidence from Canada suggests that although many hospitals have directed their attention to acute service provision, ongoing patient support related to secondary prevention has not been adequately addressed (Deshpande et al. 2008). A review of hospital-based stroke services over 5 years in North Carolina showed that during that period there had been almost no change in hospital programmes related to stroke prevention (Camilo & Goldstein 2003). Further, in the Netherlands, a study by Boter (2004) showed that the quality of life deteriorated significantly in the post-discharge period and that about 50% of stroke survivors were dissatisfied with the care provided after discharge.

There have been 21 studies (one being an RCT) describing the application of telestroke in rehabilitation. Most of the studies have described the use of technology solutions, principally to support rehabilitation activities (Hersh et al. 2006).

Joubert et al (2006; 2008a; 2008b) examined the effect of a telemedicine intervention on risk factor management and depressive symptoms in the ICARUSS study. Despite the published importance of implementation of best-practice management principles, this is the only telestroke study that has addressed risk factor management directly and shown results in an RCT. The intervention in the trial was telephone contact with patients and carers, and bi-directional information sharing between coordinator, patient and general practitioner using telephone and facsimile, coupled with data management, surveillance and response through a web-based EDC. Telephone contact between stroke specialist and primary care physician was maintained by telephone. The target populations were patients, carers and general practitioners. In this study, there was a significant improvement in a variety of measures such as risk factors, BMI, physical activity, and disability as measured by modified Rankin score (mRS) in patients exposed to the telestroke intervention compared to usual care. Moreover, depressive symptoms were significantly reduced in the telestroke group.

Support for caregivers and stroke survivors

About 80% of stroke survivors are reliant on family caregivers for emotional and physical support, ranging from assisting with activities of daily living, to arranging and escorting to medical appointments. These caregivers are often elderly, some infirm. Caregiver failure or collapse is more a cause for stroke survivor institutionalisation than is commonly realised. If the carer can be "enrolled" and supported in the role of a member of the team there is an increased likelihood that the stroke survivor will remain in the community (Grant et al. 2002).

The Internet-based support study by Pierce et al (2004) highlights caregivers' need for emotional and social support, and the general acceptance of a telestroke support system. Pilot work had indicated that a major issue identified by caregivers was the need to increase their level of knowledge about stroke in general, which the Internet-based study attempted to rectify.

Important issues of acceptance by stroke survivors' caregivers was emphasised in the study by Buckley et al (2004) who found that to some, new technology presented an extra burden.

Some caregivers only wanted simple telephone support. In this study, it was evident that the nurse's support was paramount.

Assessment of the caregiver appears to be an important measure. An evaluation of their level of technical competence, their fear of intrusion into their privacy and their desire for inclusion into a telestroke system should be carried out. Often overlooked issues include the functional ability of the caregiver, the amount of time able to be provided by the caregiver, the number of individuals sharing the burden, and involvement of the caregiver in management planning prior to discharge (Grant et al. 2002). These studies emphasise the fact that there is an unmet need in caregivers, but that the solution is probably not simple, and that telestroke support to this important group needs further study.

Coaching the Primary Care physician

In the study by Boter et al (2004), patients and carers were advised to seek help from primary care physicians if the situation warranted this. The contact and coordination with primary care physicians was more directed and active in the study by Mayo et al (2008) but neither provided and supported the general practitioner in risk factor management. In the Australian ICARUSS model, there is bi-directional information sharing regarding risk factor status of stroke survivors between the coordinator, specialist stroke services and primary care physician (Joubert, Joubert et al. 2008). Reaction to persistently abnormal values is an integral part of the EDC. The telephone support from the specialist physician to the primary care physician is part of the "shared care" component of ICARUSS. In this model, screening for symptoms of depression is done on a three-monthly basis and the results faxed to the primary care physician.

Highlighting specialist stroke services and the coordinator's role

ICARUSS also provides an example of a telestroke model that maintains specialist involvement throughout. The immediate, real time potential specialist support to the primary care physician provides the "contemporaneous sharing of responsibility" between primary care physicians and specialist, which is the element of shared care. The coordinator plays a key role in all the telestroke models for stroke survivors described below in section 3. In some, the role is passive (Camilo & Goldstein 2003) while in others (Grant et al. 2002; Joubert et al. 2008a) the interaction is more active. The coordinator plays a role in problem solving, education, surveillance and reaction as well as psychological and social support. In ICARUSS, the coordinator is the link between patient, caregiver, primary care physician and the specialist stroke services. Interestingly, the results of the latter models were significantly more positive compared to the former studies.

2.4 Telestroke for overall stroke management and education (patients and professionals)

The Recommendations for the Establishment of Stroke Systems of Care by the ASA task force state that:

"A stroke system should develop support tools to assist the population as a whole, patients and providers in long-term adherence to primordial and primary preventive treatment regimens" (Schwamm et al. 2005).

Indeed, stroke programmes have a vital role to play in educating the public and primary physicians about risk factors, symptom management, and stroke prevention (Moulin & Hommel 2005). Telemedicine can be particularly useful in applying this recommendation to

populations or communities in rural or under-serviced areas. Appropriately timed educational videoconferencing by stroke experts may be useful not only in forums open to the general public, but also for patients, carers, nursing and allied health staff as well as medical personnel. Topics that can be covered are signs and symptoms of cerebrovascular disease, acute treatment options, in-hospital management and implementation of preventive strategies. Virtual contact with the opportunity for discussion as a supplement to written guidelines may be particularly valuable and should be the subject of future research. This is separate from the educational aspects of the virtual neurological telestroke conferencing described above.

Awareness of signs of stroke is variable, particularly in rural areas. In Montana, a telephone survey of 800 rural residents revealed that 70% were able to identify 2 or more warning signs, although only 38% recognised that speech difficulty was a sign of a stroke. In West Virginia, only 20% of residents were able to identify all stroke warning signs, most were unaware of the importance of loss of vision and severe headache as indications of stroke. The results of a survey in northeast Bulgaria by Dokova et al (2005) were similarly disappointing and a study in rural Georgia, USA, also revealed a low level of awareness of stroke warning signs. Although 48% of respondents had experienced a stroke in the family, and 95% considered stroke an emergency, only 39% of 602 adults could name 1 or more stroke warning signs in response to unaided questions. A component of the current web-based support tool for rural caregivers in rural Ohio and Michigan is raising the awareness of features of stroke in caregivers. Stroke signs were readily identified by Tsongan and Mozambican populations, but the reaction was to consult traditional healers (Hundt et al. 2004).

Awareness of risk factors for stroke is equally as patchy, and again, particularly in rural areas. In a rural Mennonite community study by Michel et al (1993) only 8% of the study population had ever been screened for serum cholesterol, despite the fact that one-third of those over the age of 55 years had either had a stroke or a myocardial infarction. Cooper et al (2005) reported that in sub-Saharan Africa hypertension awareness rates were as low as 20%, and in a Montana-based study by Blades et al (2005), only 44% of the participants were able to identify hypertension as a risk factor for stroke. A rural-urban study by Hu et al (2000) in a population of 35 years and older in China showed that awareness of hypertension was 2.6% in rural populations compared to 4.4% in urban ones.

Risk factors for vascular disease including stroke are on the increase. Examples of this are the obesity epidemic, the increase in diabetes and prevalence of raised blood pressure, particularly evident in the developed world, but also strongly predicted in the developing world (Beaglehole et al. 2007; Thompson & Hakim 2009).

Telemedicine opens the possibility for primordial prevention in communities. Individuals at risk, as identified in clinics or by primary care physicians or nurses, family members of stroke victims and other members of the general public, could all be targeted for teleconferencing from stroke centres. This aspect of the prevention of stroke has been sorely neglected. Telemedicine as a modality of education in stroke prevention clinics has not been studied and deserves evaluation as to whether it is equal to or an improvement on current modalities of education, and in fact whether it can be used as an adjunct to these modalities (Hachinski et al. 2010).

3. Telestroke requirements

3.1 Technology options for telestroke

A range of generic and personalised technology options have been used in different studies, including telephone, facsimile, email, videoconferencing, and internet-based communication.

Use of telephone

Simple telephone contact has been shown to be useful in different situations, such as giving practical problem-solving advice to caregivers. Moreover, the contact was useful in reducing stress in a study by Grant et al (2002). Telephone interviews have been shown to be reliable in the application of a variety of assessment and measuring tools, such as the Stroke Impact Scale (SIS) (Kwon et al. 2006), and proved reliable for evaluation of function, disability and cognitive function in community outpatients (Meschia et al. 2004; Merino et al. 2005). Telephone administration of the Patient Health Questionnaire (PHQ9) has been validated in stroke patients (Lee et al. 2007). This instrument has demonstrated reliability as a screening tool for Post Stroke Depression (Williams et al. 2005). There is a need to determine the best modality for achieving the requisite goal in stroke survivors. These goals may be risk factor modification, patient and carer education, detection and management of post-stroke depression, carer support, strategy implementation, rehabilitation or simple surveillance of health service usage. Different modalities may be appropriate for different goals in that simple telephone calls may suffice for patient and carer education or support (Grant et al. 2002; Buckley et al. 2004), whereas videoconferencing would be required for a tele-rehabilitation programme (Hersh et al. 2006), or a psychiatric intervention for depression (Doze et al. 1999).

Use of Videoconferencing

Videoconferencing enables the patient, the caregivers, and the local and distant physicians to interact visually and audibly. However, minimum specifications need to be determined on the technical aspects including the degree of resolution of the computer screens and bandwidth to transmit videoconferencing and images. Some studies have also indicated that sound quality needs to be improved (Audebert et al. 2005; Meyer et al. 2008).

In order to address these technical issues, the following requirements have been proposed: a remote-control camera with zoom, tilt and rotation functions at the distant or "spoke" hospital, and large monitors with high resolution are needed in both the "hub" and "spoke" hospitals. To maintain sufficient visual quality (25–30 frames per second), a bandwidth of at least 300 kilobits per second is required (Audebert 2006). A controlled trial, allocating hospital-based or mobile teleconsulting and evaluating technical parameters, acceptability, and the impact on immediate clinical decisions showed that critical treatment decisions can be made on the basis of laptop-based telestroke consultations using the available European mobile network technology. However, although the technical quality was sufficient to make relevant immediate clinical decisions, the quality of the video examination was considered inferior to hospital-based consultations and there were critical comments regarding the lack of a video stream on the spoke side (Audebert et al. 2008).

Innovative Technologies

The literature reveals an interest in experimenting with new information and communication technologies from videoconferencing, Internet web-cams, to virtual reality haptic workbenches. Indeed, technological advances and developments in communication methods have led to new ventures within the field of telemedicine, and more specifically, telestroke. For example, Covotem™ Video Solutions is a telestroke tool that has been developed for emergency stroke treatment and secondary prevention. It comprises a software platform, HD videoconference and a high quality sound system. Covotem™ enables the neurologist to remotely manipulate a motorised camera in order to dynamically

visualise the patient. A graphical editor enables medical imaging to be shared in real-time in DICOM format so that the type of stroke can be diagnosed and thrombolysis administered if necessary. Patient data can also be shared via an electronic file. This is just one example of the way in which information technology has taken giant strides in developing effective and efficient tools for delivering health services to widely dispersed populations.

3.2 Telestroke models: organisation and networks

Primary Stroke Centres (PSCs)

The overriding theme supporting the organisation of any model of telestroke care, particularly in the acute stage of stroke, is the availability of centres of excellence (PSCs) that are accredited and conform to requirements that enable them to not only be resources for the administration of rt-PA, but also act as “mentors” for hospitals receiving acute cases that are appropriate for thrombolysis, but which do not have the expertise or resources to implement the treatment without support.

Recommendations for such centres that would improve the treatment of stroke patients in the acute stage were determined by the Brain Attack Coalition (BAC) in 2000 (Alberts et al. 2000). These recommendations consisted of a number of constituent features such as the formation of acute stroke teams, the availability of 24 hour brain imaging and written protocols for the administration of rt-PA.

The BAC has determined optimum time-guidelines for patient triage and evaluation. They have determined that a stroke team should evaluate potential stroke patients within 15 minutes of arrival at the emergency department. This guideline in itself shifts priorities in a busy emergency department for the rapid evaluation of the stroke patient which is very different from the situation in the pre-thrombolytic period. Following this, computerised tomography (CT) of the brain should be performed within 25 minutes and reported on within 45 minutes. Ideally, in eligible stroke patients, intravenous rt-PA should be administered within 60 minutes (Switzer & Hess 2008).

The above rapid response has been sadly lacking, not only in community and rural hospitals, but also in major urban hospitals. The ideal of rt-PA administration within 60 minutes of arrival was only achieved in 16% of patients receiving thrombolytic therapy in a recent study by Reeves et al (2005) of hospitals from four states in the US.

Nevertheless, there have been gains and a demonstrated reduction of the delay between the presentation of a stroke patient at hospital and the appropriate administration of rt-PA, indicating that with guidelines and structure, systems of management can be changed.

Following the recommendations of the BAC, the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) commenced the certification of these, and according to a review in 2008 by Switzer and Hess, there were over 300 JCAHO-accredited PSCs in 40 states as well as the District of Columbia.

The Complete Telestroke Model

A fully developed telestroke network involves the expertise from the PSC being directly applied to the clinical situation. Contact with the patient and family can be made via a video link, and NIHSS scoring performed by the PSC neurologist. Moreover, transfer of radiological data takes place, and CT reporting is done from the PSC. For this to function well, reliable video contact and ability for image transfer is mandatory. Another requirement is that the PSC or “hub” hospital has around-the-clock availability for

teleconsultation. This will often only be possible from larger academic centres, with adequate staff components. Experienced stroke physicians will be able to read CTs adequately, but in large centres, radiological cover is frequently present for early evaluation of CT images.

For the most part, the model is a “fixed-site” one, which promotes high quality video and audio communication. In the “site-independent” model, connection is via the internet and often video quality is poorer than in the fixed-site model.

The “hub and spoke” model has been adopted widely in both the United States and Europe. Examples of such models of telestroke in the United States have been the Remote Evaluation of Acute isChemic stroke (REACH) programme in east-central Georgia (2008–09.), the Partners Telestroke Center in Massachusetts and Stroke Telemedicine Initiative in New York State. In Europe, effective telestroke projects such as the Emergency Neurology Network in Franche Comte (RUN-FC) (Moulin et al. 2004), and the TEMPiS project in Bavaria (Audebert et al. 2005) have been in existence since the early part of the millennium. Despite varying emphases and differences in the model details, all have in common the expedition of treatment of acute stroke and the apposition of specialist stroke services and often remote, under-serviced hospitals by technology.

The development of variant interhospital collaborative models for acute treatments

Due to the large variation of hospital resources, both in urban and rural settings, the most efficient, practical and achievable model has to be identified (usually by the spoke hospital). This of course can change as the spoke hospital staff become more familiar with administering rt-PA. However, for the main part, between PSCs and spoke hospitals, established models of management of acute stroke cases have been developed. In addition, there is an increased risk of complications in situations where there is intermittent or infrequent administration of rt-PA, and an efficient mentoring relationship with a PSC is of great value to the community especially remote hospitals in managing the process (Heuschmann et al. 2003). In this regard, a mentoring role of academic hospitals and other PSCs has developed three major models of collaboration.

These models link community and other hospitals, especially geographically isolated ones, with centres that regularly and expertly use thrombolysis.

- *“Call and ship” model*

This is the most common model of expedition of thrombolysis in urban areas in the industrialised world. It is not a traditional telestroke model except that there is initial and sometimes ongoing contact (telephone or radio) between EMS and the PSC, but it emphasises a rapid response and evaluation on the part of the EMS with rapid transport to a PSC.

Here, the EMS identifies an appropriate stroke patient, contacts the PSC and then transports the patient via MICA ambulance or whatever is the most rapid means to the PSC or specialist stroke service.

One of the difficulties in this model is the misdiagnosis of stroke. Thrombolysis is only safe and effective in selected cases of cerebral infarction, and would be disastrous in the context of cerebral haemorrhage. Inherent in this model is the inability to identify cerebral haemorrhage accurately on clinical grounds (Crocco et al. 2003), as well as the variability of accurate stroke diagnosis by ambulance personnel. The sensitivity of stroke diagnosis varies widely (between 61% and 94%) and positive predictive values remain low (Rajajee & Saver 2005). Two screening tools exist; both designed to aid the pre-hospital identification of

stroke by EMS. These are the Los Angeles Pre-hospital Stroke Screen (LAPSS) (Kothari et al. 1997) and the Cincinnati Pre-hospital Stroke Scale (Kidwell et al. 2000). Through use of the LAPSS in both California and Houston, Texas, the sensitivity of stroke diagnosis increased substantially. In Los Angeles, sensitivity was 91% and positive predictive value for stroke diagnosis was 97% (Switzer & Hess 2008).

Other factors do play a role, such as traffic conditions and misdirection to hospitals that do not have the expertise to administer rt-PA. In the United States there are only three states (Florida, Massachusetts and Texas) where it is legislated that the EMS takes stroke patients to a certified PSC (Switzer & Hess 2008).

Video assessment in ambulance cars was used in the TeleBAT system of the University of Maryland's Brain Attack Team (LaMonte et al. 2000). Low mobile transmission rates of 9.6 kbps only allowed transmission of two frames per second along with a voice channel. However the authors demonstrated the feasibility of performing the NIHSS evaluation in a specially-equipped dedicated ambulance. Video examination in the ambulance car is also currently being evaluated in Berlin using real patients and much higher transmission rates. The next step will be a controlled trial comparing stroke admissions by telemedicine-armed ambulance and by normal ambulance cars (de Bustos et al. 2009). It is clear that existing technology can provide some degree of interactive video and audio communication with pre-hospital units in transport, although current published applications have unacceptably low frame rates, and broad application of this technology to large fleets of EMS vehicles is not yet practical. Providing stroke expertise to the ambulance via HQ-VTC may increase diagnostic accuracy, provide earlier resource mobilisation, and increase appropriate triage. Furthermore, if effective pre-hospital neuroprotective interventions are available in the future, telemedicine may increase their appropriate use (Schwamm et al. 2009).

- *"Ship and Drip" Model*

This model embraces rapid communication between a community hospital and the expedited transport of an appropriate candidate for thrombolysis from that hospital to a PSC, where final evaluation and treatment can take place. Two PSCs in London and Ontario, Canada, have acted as hub hospitals for 33 spoke hospitals (Merino et al. 2002). Often basic facilities for evaluation and treatment such as CT scanners were not available in the spoke hospitals. In the London experience, of 82 consecutive patients undergoing thrombolysis in these two PSCs, 23 were transfers from rural spoke hospitals. Interestingly, patients referred had a shorter onset to treatment time compared to stroke victims presenting to London Emergency departments (148 minutes compared to 172 minutes). The essential decision in this model is whether the patient can be transported within the three-hour window. The Canadian study showed that this method can be applied with good effect. It is, however, not the most effective (Switzer & Hess 2008). The inherent difficulties in this model are availability of transport and time of transport. It is a model that could be greatly enhanced by telestroke communication.

- *"Trip and Treat" Model*

In this model, one that has been tested with good effect in both Houston and Cincinnati (Grotta et al. 2001), the stroke specialist is transported from a PSC to the patient judged appropriate for thrombolysis in a community hospital. It depends on several features that are different from the "Ship and Drip" model. These are: availability of CT facilities at the community hospital, adequate transport and availability of staff at the "hub" hospital to travel. This has been shown to be feasible in urban settings. For instance, the Cincinnati Stroke Team serves a ring of 22 surrounding hospitals. Inherent in this model is the problem

of navigation of urban traffic. It is essentially an urban model reliant on large academic institutions with large staff components.

- *“Drip and Ship” Model*

In this model, which is closer to the ideal telestroke model, the appropriate patient is treated in a community hospital with intravenous rt-PA, and after this, is transferred to a PSC. In this model, the initial evaluation of the patient and CT are made at the community hospital site with thrombolysis commenced at that hospital. The initiation of thrombolytic therapy is done with telephone support from the PSC. There is no video contact between the two hospitals and no transfer of radiological data. Transfer of the patient takes place by whatever means is available. Intravenous rt-PA is frequently kept running during the transportation. On arrival at the PSC, the patient is evaluated for possible intra-arterial therapy. The deficits inherent in this system are inaccurate evaluation both of onset and physical status of the patient, and the inaccurate reading of CT scans. Non-neurologists making decisions and unavailability of radiological cover can give rise to less than optimal evaluation. Despite these drawbacks the model has been shown to be effective in several studies (Wang et al. 2000; Rymer et al. 2003; Frey et al. 2005).

4. Barriers to the implementation of telestroke models

4.1 Technical advances

One of the major barriers to the success of telestroke is that, despite the numerous advantages of recent technological advances, technical problems arise with telemedicine technology, including non-connecting or malfunctioning devices. This problem must be eradicated since it can lead to distrust by users and low levels of satisfaction, which can be further aggravated in cases of lack of interoperability due to fears of rapid obsolescence and wasted capital.

In terms of telemedicine-directed stroke care, there have been 3 different methods used for interaction: (1) telephone service; (2) HQ-VTC with an on-call stroke team using an Internet-based wireless or high-speed landline connection; and (3) a combination of telephone and video methods. Each of these methods has strengths and weaknesses, and several trials are seeking to determine whether videoconferencing is superior to exclusively telephonic interaction (Schwamm et al. 2009).

Despite innovative technological solutions making medical imaging available for simultaneous viewing by spoke hospital personnel and the telestroke consultant, which reduces the number of individuals required to make definitive recommendations regarding thrombolytic therapy or other time-critical interventions, many rural areas (as well as some urban and suburban areas) do not have access to consistent low-latency, high-speed bandwidth sufficient to support reliable, high quality video transmission and reception over open, standards-compliant networks. The presence of essential infrastructure (telephone lines, wireless broadband) must be assessed for hospitals participating in the exchange of telemedicine data as part of an SSCM implementation. Effective information technology systems and supporting infrastructure need to be put in place to initiate a telemedicine programme for stroke treatment. For example, the mode of data transmission must provide adequate bandwidth to transmit large amounts of data quickly, accurately, and securely.

The fact that the spectrum of IT options is expanding rapidly, whilst costs are decreasing, is perhaps more important. However, deployment of these options is not uniformly available across all geographical and demographic users. Fibre-optic cable is not yet as ubiquitous

and high bandwidth mobile phone networks (such as G3) do not have the same coverage as GSM (Webb and Williams, 2006). More importantly, money is often spent on technical equipment but not sufficiently on the personal resources needed in telemedicine services.

4.2 Costs of infrastructure and staff

For a PSC to function as a centre of excellence that supports thrombolysis for remote hospitals, there are two main cost areas; one being the infrastructure set-up and the second has to do with staffing. In terms of infrastructure, the issues such as the acquisition of computers, the software related to these as well as the setting up of a system of data transmission that is in accordance with Privacy Guidelines for the specific country have to be resolved at a local level. The second problem of staffing relegates the setting up of telestroke networks to hub hospitals that have large numbers of staff, such as large academic departments. These hub hospitals take on the responsibility of providing access to stroke experts 24 hours per day, providing education to spoke hospital staff in how the process functions, providing systems for acquisition of images and, if necessary, having neuroradiological support available on a round-the clock basis.

Accessibility to necessary technology that is mandatory for the transfer of data from spoke to hub hospitals has varied in the past. However, increased availability of broadband nationwide has recently taken place due to a government initiative in Australia, and incentives for installation of fibre optic cabling to facilitate to high-speed Internet is an ideal that rural health care providers and local government should consider. However, due to economic factors, particularly in the developing world, there will always be barriers to attaining the ideal of good connectivity. Therefore the different modalities of telestroke connections such as Plain Old Telephone Service (POTS), cellular telephone network, HQ-VTC via Internet based wireless or high-speed landline connection as well as a model employing a combination of these methods, will vary from country to country, and the formation of a telestroke service should make use of existing and feasible technology as well as creativity.

Despite the fact that there is sufficient data to show that telestroke programmes increase the use of thrombolytics and in doing so reduce long term disability, there are few data concerning the economics of the programmes as a whole. Collection of health economic data concomitantly with clinical data is essential in future studies, not only in determining the economics of thrombolysis, but also the effect of telestroke programmes on risk factor management and thereby reduction of recurrent stroke and a step-wise decline into dependency. In a recent Danish study by Ehlers et al (2008), which looked at the cost-effectiveness of rt-PA administration between 5 centres and 5 clinics, the additional costs in this model over one year were \$3 million. In the first year, the incremental cost-effectiveness ratio from Telestroke was around \$50,000 per quality-adjusted-life-years (QALYs). In the second year, the telemedicine model was both less costly and more effective due to less expenditure in rehabilitation and long-term care.

Apart from cost-effectiveness, the cost in terms of resource utilisation, investment costs and maintenance costs has not been rigorously studied in the area of telestroke models (Johansson & Wild 2010). The German TEMPiS study was evaluated to cost €300,000 per year. When teleconsultation expenses were subtracted, the net cost ranged between €19,200 and €56,000 per year (Audebert et al. 2005). A telestroke system requires an initial capital expenditure in terms of equipment, maintenance, education of staff and support. Apart from

these costs, telestroke networks require teams of on-call doctors as well as administrative and nursing staff. If the telestroke model uses the “drip and ship” approach, then the costs of transport have to be factored into the whole equation.

4.3 Funding and reimbursement

There are two main issues with reimbursement. The methods of how the referring and the consulting physician are reimbursed vary from situation to situation depending on the country. The situation becomes more complex when cross-border referrals are made. The second is the reimbursement of hospitals themselves. In the United States, as a result of the additional costs of special monitoring of patients who have been administered rt-PA, Medicare and others have developed a new coding system that covers the ancillary costs (Schwamm et al. 2009). There are complex issues regarding reimbursement in those patients who are transferred to a hub hospital. In particular this applies to cases where the “drip and ship” model is used. All in all, with a telestroke intervention, in addition to the cost of the drug itself, the overall cost includes the reimbursement of personnel and the cost of setting up the system, coupled with the training of all the healthcare participants.

4.4 Legal, deontological and ethical issues

General Background

The development of ICT over recent years is an incontrovertible fact and this has had an inevitable impact on medical practices. However, the majority of doctors have been unable to keep up with the speed and complexity of technological advances, and this has given rise to a number of bioethical issues (in the sense that ethical questions arise from the development of biotechnologies).

Just like progress in intensive care medicine has led to the concept of brain death or the potentials of medically-assisted procreation have led to reflections on assisted reproduction and filiation, the practice of telemedicine raises issues relating to the doctor-patient relationship and the freedom and responsibilities of the doctor. From a deontological perspective, the practice of medicine is an independent (exempt from material or moral pressures), personal and free act, but with this freedom comes responsibility. These principles are bound by competence, and the law specifies that if the attending physician does not possess the sufficient knowledge or technical know-how, he or she must call upon the expertise of a more specialised colleague. The attending physician assumes the responsibility for this step, even if only in the choice of specialist, and at this point is still the patient's interlocutor, notably in deciding whether or not he or she will follow the advice given.

The doctor-patient relationship is therefore very much a two-way relationship, and should ideally be fostered in a safe environment, enabling the flow of inter-subjective and ultimately non-verbal information (mimic, jests, attitude, etc.).

The practice of telemedicine introduces a whole new dimension: communication is established at a distance using images and/or sound, in real time or asynchronously, and with a “virtual” doctor whose advice has a determining impact on the patient's health. This advice may be given to the “real” doctor at the patient's bedside (teleconsultation), or when reviewing a patient's file in the absence of the patient (tele-expertise). These situations do not result from any active choice made by the patient; they arise as the result of various “objective” constraints, some of which are linked to health policies such as doctor shortages,

hospital closures, insufficient technical platforms, geographical remoteness of a centre of reference, etc. On the other hand, the use of telemedicine is also a clear expression of the progress that has been made, not only in the area of telecommunications, but also of medical techniques, some of which can only be employed at a highly specialised level. These ICT advances can be used to bring about real improvements in sound quality, and to compensate for certain insufficiencies or deteriorations to the healthcare environment. However, patients may be surprised, or even unsettled, by this wave of new technologies, which is why particular attention should be paid to ensuring that patients are sufficiently informed before giving their consent. In this regard, for instance, the fact that the French medical council recommends that patients sign an information letter is evidence of the unusual nature of the doctor-patient relationship. If a patient is unable to give his or her consent (reduced alertness or aphasia), the use of telemedicine is determined by therapeutic necessity (i.e., article 16-3 of the French civil code).

In the context of tele-expertise and teleconsultation, the roles and subsequent responsibilities of the different doctors who intervene can be particularly difficult to define. This issue is even more complex due to the general lack of legal provisions and clarity concerning this new practice. However, these difficulties should not be used as a pretext for inaction. The essential drive for the development of telemedicine will surely come from the willingness of doctors to collaborate with each other, to define and formalise their responsibilities (conventions, protocols) and to enrol their patients in these new practices if they are convinced of their effectiveness. In such circumstances, the general legal approach in terms of responsibility is that each actor (doctors and healthcare institutions) must answer for their actions according to their actual or assumed competencies. Thus the attending physician, for example, must gather the necessary information (through questioning, clinical examination, details from the patient file) which can be given when requested to the virtual doctor, who must therefore then take responsibility for his recommendations (Contis 2010).

Patient Confidentiality

Another characteristic of the doctor-patient relationship is that it is governed by the rules of patient confidentiality. It is the doctor who is responsible for ensuring that the existence and the nature of all patient consultations remain confidential. The digitisation of data, computerisation of patient files and the use of new ICT make it more complicated to monitor health-related information. It means that doctors have to hand over part of their responsibility to machines, procedures, software, and more generally to technologies of which they are not in full command. With the use of telemedicine, health-related data and its confidential nature is inevitably shared. The challenge involves limiting this information sharing to the necessary, and giving the patient a certain amount of say over what is transmitted.

The choice by the doctor of the relevant data can be difficult: in certain cases, it involves the results of complementary examinations or technical data, but in other cases, elements of the patient's personal life, his or her personality, or the tone of the relationship that he has with the doctor can be factors that influence the choice of treatment. It remains unclear how these more sensitive factors would best be communicated if patients were to exert greater control over the nature of the information transmitted, the risk being that it may become progressively excluded from the sharing process. For example, in France, although article n° 2002-303 of 4th March 2002 declared the principle of "express" consent for the hosting of health-related data, article n° 2007-127 of 30th January 2007 states that an exemption is

possible when the host is in agreement and the data are transmitted by a professional or a healthcare institution. In other words, digitised personal health data can be physically transferred and stored without the patient knowing. It is therefore important to be able to trace, archive and store these multiple files which are essentially a record of an individual and personal medical event, and which may need to be shared, but must also remain confidential.

Community and emergency physicians' attitudes and medico-legal liability

In situations where intravenous rt-PA is administered by inexperienced physicians or by physicians who very infrequently use thrombolysis, it has been shown that complications such as intracerebral haemorrhage are more common than when the evaluation of the patient and the administration is performed by doctors who do it frequently (Katzan et al. 2000). Brown et al (2005) reported that the fear of complications is the main reason for 40% of emergency physicians not using rt-PA. This is driven by the fear of litigation. Conversely there is a medico-legal danger in not administering thrombolysis in appropriate patients. In a review of litigation related to the use or non-use of rt-PA (Demaerschalk & Yip 2005), in those cases where the outcome was in the plaintiffs favour, 83% related to failure to treat, whereas complications of treatment were only cited in 17%. Nevertheless, there is a significant number of doctors who choose not to expose themselves to situations where decisions regarding thrombolysis may need to be made for both these reasons and also because they do not wish to carry the on-call and after-hours responsibility.

Because of the risk of medical liability in not providing rt-PA in spoke hospitals, a telestroke programme involving expert "supervision" and, if possible, video assessment of the clinical status of the patient can be of great benefit for the spoke medical personnel. Accurate documentation of the clinical situation by both ends of the telestroke team ensures that medical liability for withholding treatment and complications resulting from the treatment is of great value for a spoke hospital (Liang & Zivin 2008).

Telestroke is a recent addition to the armamentarium of the community or rural physician and even urban physicians outside stroke centres. There is an understandable lack of trust and familiarity with the process because of this. Rates of telestroke referral and contact between spoke and hub hospitals vary considerably both in Germany (2% vs. 86% (Wiborg & Widder 2003), and the United States (Nesbitt et al. 2000). This lack of trust and reluctance to participate on the part of the spoke hospitals can be overcome in a number of ways. Involving the spoke hospital, nursing and administrative staff at an early stage in the process of setting up a spoke site, leads to them being able to "buy in" to the process. Other methods would be to have information and educational sessions with clear delineation of duties of nursing and medical staff. Ultimately, telemedicine is an indicator of the development of medical practices, and has an impact on both patients and doctors. It enables the diffusion of advanced treatments and techniques through the remote transmission of procedures and knowledge, and provides access to ultra-specialised expertise. It reveals the development of the doctor-patient relationship which is becoming more and more technical at the risk of becoming dehumanised. This may be accentuated by collaborative efforts between doctors which only take into account the objective elements, and overlook the importance of subjectivity when treating patients. Finally telemedicine highlights the dangers involved in the digitisation and diffusion of personal data.

5. Future trends and recommendations

Experiences have clearly demonstrated the wide-ranging current and potential benefits of telemedicine applied to stroke. Telestroke effectively links remote hospitals and underserved areas to PSCs, bringing effective therapies to patients in these areas. The impact of telestroke in implementing thrombolysis is well established and many other important benefits have now emerged, notably in the areas of stroke rehabilitation and secondary prevention. Therefore, as emphasised by Tatlisumak et al (2009), telestroke should be understood as a versatile tool which is not limited to delivery of thrombolysis, but offers numerous other benefits to stroke patients in underserved regions.

However, despite these demonstrated benefits, telestroke is currently not being used according to its full potential. Major advances will only be achieved in the future if the main barriers hampering the wider use of telemedicine, most of which have been identified, can be overcome.

As information technology continues to advance, it will be important to ensure that medicine is able to leverage and optimise the benefits of these developments. One of the top priorities will involve providing essential infrastructure to remote rural-based hospitals. The need for enhanced connectivity to rural areas urgently needs to be addressed. This could be partially achieved through the launch of dedicated programmes, such as the Federal Communications Commission's Rural Health Care Pilot Program in the United States, which offers huge discounts to collaboratives of rural health facilities that install commercial fibre optic cabling for access to high-speed internet. In addition, the rapid pace of technological advances will demand resolution of technical issues, facilitation of market development, and repeated assessment of the appropriate quality standards in health-related telecommunication (de Bustos et al. 2009). After all, patients will be much more inclined to partake in telemedicine if they believe they can do so privately and safely, and trust both the physician and technical provider. Alleviating patient concerns about the confidentiality of health-related information is therefore an important goal. This will be further facilitated by ensuring that all hospital staffed involved (specialists, emergency physicians, nurses, admin staff) have a positive attitude toward telemedicine practices by providing them with the necessary information and training.

As telemedicine also introduces a new form of interrelationship between health care providers, mutual trust and acceptance need to be developed here too. Indeed, in order to progress from small scale pilot projects to the national deployment of telemedicine, there is a pressing need for political will. This will help to overcome barriers such as the reimbursement issue, and will essentially involve convincing healthcare providers that telemedicine does have added value by providing them with information on evidence-based cases.

Further advances need to be made relating to legal clarity to ensure that the development of telemedicine is not hindered by legislation that is stuck in the past. Cross-border provision of telemedicine services requires legal clarification on an international basis. For instance, some EU states have clear legal frameworks for enabling telemedicine, whereas in other countries, the laws require that the acting health professional is physically at the same place as the patient. This is a clear obstacle to the deployment of telestroke and highlights the need for standardised regulations to address the medical liability associated with telemedicine-enabled care. As suggested by de Bustos et al (2009), the fact that teleconsultations in acute stroke are very similar to onsite stroke consultations should facilitate these regulations.

Finally, continued efforts must be made to continue to further develop the widespread deployment of telemedicine to the areas of stroke rehabilitation and secondary prevention in order to reduce the impact of problems such as post stroke depression in stroke survivors, and to stem the increase in stroke-related risk factors. Therapeutic inertia associated with the long-term management of these risk factors remains common at primary care level and in order to address this, a combination of a 'hub-and-spoke' case management model (care coordinator, with multiple stroke survivors) with a linear 'top-down' model (specialist, coordinator, carer, patient and primary care physician) could be advantageous. The ICARUSS model by Joubert et al (2006; 2008a; 2008b) provides an example of a telestroke model which specifically supports the implementation of secondary stroke prevention strategies and the detection of post stroke depression. Hersh et al. (2006) found that there were only a small number of well-designed telestroke studies, particularly in rural settings. There is a need for more rigorously designed randomised controlled trials and longitudinal observational studies of clinical outcomes to demonstrate the effective use of telemedicine in stroke survivors discharged from hospital (Lewis et al. 2006).

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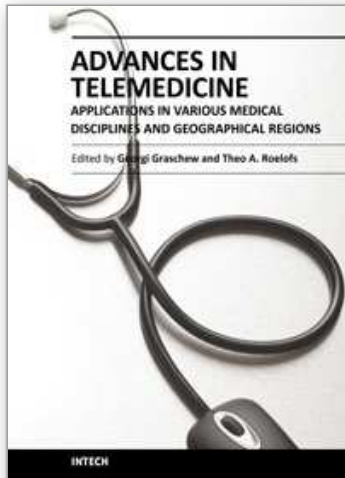
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Innovative developments in information and communication technologies (ICT) irrevocably change our lives and enable new possibilities for society. Telemedicine, which can be defined as novel ICT-enabled medical services that help to overcome classical barriers in space and time, definitely profits from this trend. Through Telemedicine patients can access medical expertise that may not be available at the patient's site. Telemedicine services can range from simply sending a fax message to a colleague to the use of broadband networks with multimodal video- and data streaming for second opinioning as well as medical telepresence. Telemedicine is more and more evolving into a multidisciplinary approach. This book project "Advances in Telemedicine" has been conceived to reflect this broad view and therefore has been split into two volumes, each covering specific themes: Volume 1: Technologies, Enabling Factors and Scenarios; Volume 2: Applications in Various Medical Disciplines and Geographical Regions. The current Volume 2 is structured into the following thematic sections: Cardiovascular Applications; Applications for Diabetes, Pregnancy and Prenatal Medicine; Further Selected Medical Applications; Regional Applications.

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